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AT TIMBER-LINE IN THE LAND OF TAHOSA[1]

AN INTRODUCTION TO THE AGED GNOMES OF AN ALPINE ELFIN-WOOD

By RAYMOND J. POOL

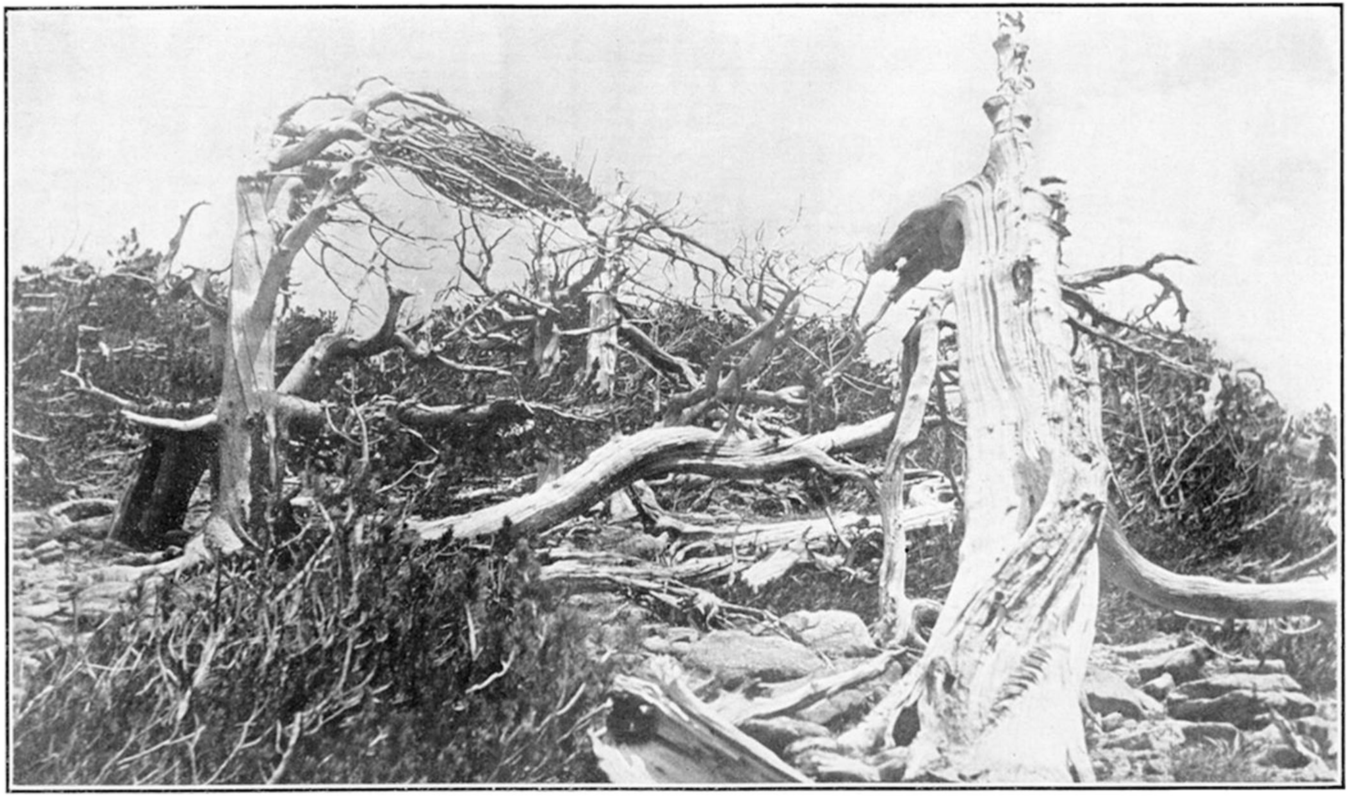
PROFESSOR OF BOTANY, THE UNIVERSITY OF NEBRASKA

FROM a land of beetling crags and tumbling cascades, from a land of snowy summits and booming storms, from a land of glacier-driven valleys and verdant forests, from a land of spire-crowned spruces and quivering aspen trees, from the land of Tahosa comes my story. Tahosa, the land whence myriads of sparkling mountain fonts bequeath perpetual laughter to the slender threads which, converging, evolve the mighty Colorado and start it on its silvery, winding way through the mighty chasm; a chasm sunken by the slowly laboring mechanic of the ages into the layered floor of that great plateau where the soft warm tones of the setting sun reflected from rugged cliff and treacherous talus mingle with the twilight haze of the great southwest.

THE LAND OF TAHOSA

Tahosa is the name that we would now use for one of our great mountain states had the request of those who petitioned for statehood been granted. "Dwellers of the mountain-tops," the name is particularly fitting for the state called Colorado, for that state claims a thousand mighty mountains which raise their rugged summits to altitudes exceeding two miles above the level of the far-off sea. There are in Colorado literally scores of mountain peaks which mount toward the sky beyond 13,000 feet, and many of these even exceed 14,000 feet. So Tahosa (if we may use the name) is indeed a place of mountain tops.

[1] Illustrations from Photographs by the Author.



THE STORY OF A TRAGIC PAST IS MIRRORED IN THE MANGLED FORMS OF THE STORM-TOSSED AND TIME-WORN TREES WHICH STAND FORTH AS THE OUTPOSTS OF THE ALPINE FOREST PRIMEVAL.

AT TIMBER-LINE

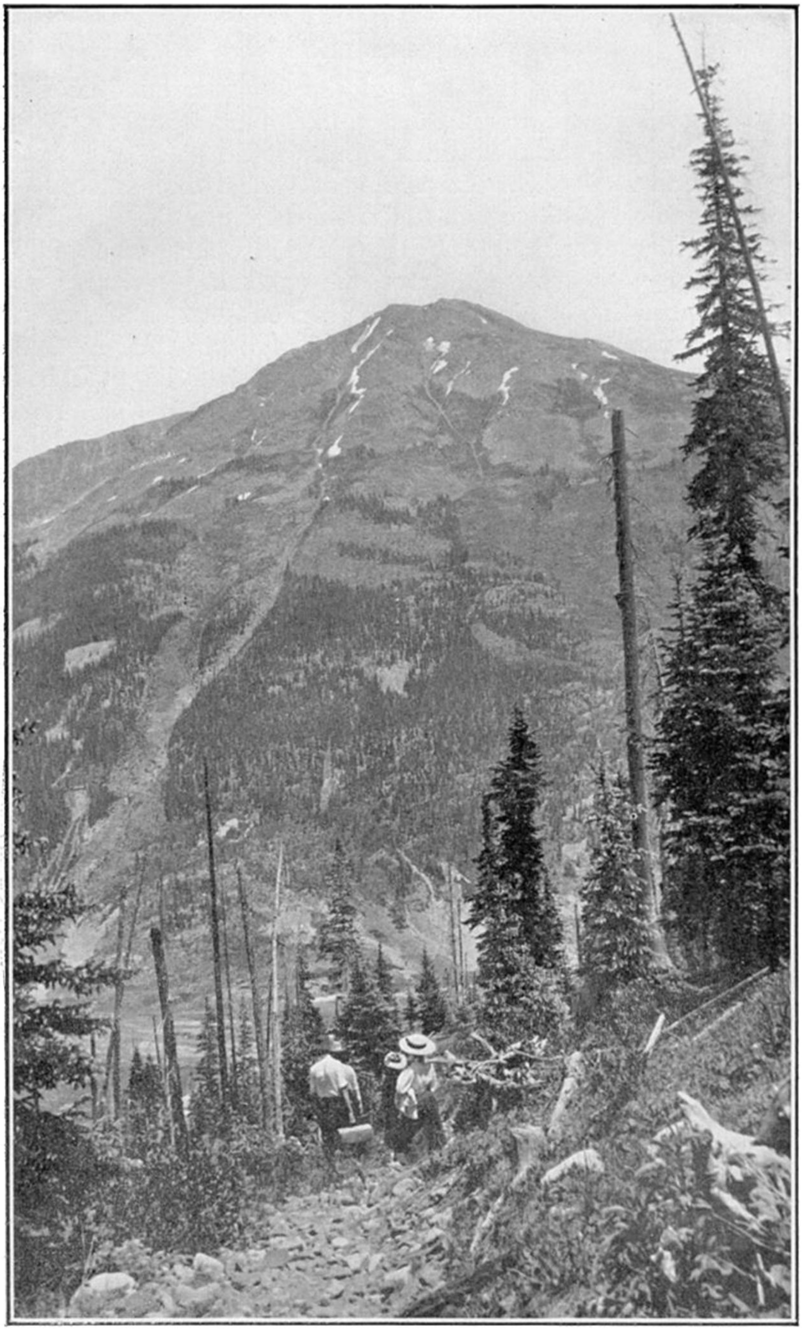
To one who loves the thrill of the dynamic landscapes of nature, and who delights in the muscular pull necessary "to go up to the sky in the mountains" there is no place at once so alluring and so thought-compelling as timber-line. The ever-changing forms and phenomena about one lure the climber to greater and greater heights. The rarefied atmosphere and an accelerated pulse draw and drive him upward.

At timber-line one beholds the upturned faces of the ancient past mirrored in the glacier-polished valleys and upon the lichen-covered cliffs of a granite cirque or in the jumbled, boulder-strewn moraine. He may read the story of a less ancient but none the less tragic past mirrored in the mangled forms of the storm-tossed and time-worn trees which stand forth as the alpine outposts of the forest primeval. The spirit of reminiscence blows full free upon the visage of those sad and tattered sentinels of that terrible frontier. One need only to possess the power to interpret the reactions of those outposts to catch fleeting glimpses of some of the most severe struggles and "last ditch" stands ever endured by living things. And I would impress my readers with the fact that these gnomes of the heights are living organisms! Many such sentries exposed to the scathing fire of a relentlessly opposing environment have, however, long since yielded up the ghost. Their whitened and eroded forms are being slowly ground away and their dust is gradually being returned to the barren earth which gave it.

The survivors at timber-line tell their several stories only to those who are acquainted with their lives and who delight in reading the dynamic life-histories and the evident struggles with environmental forces endured by poor dumb things, because the trees at timber-line, despite their expressive forms, are no more talkative than their close relatives who enjoy the equanimity of the mesophilous lowland forests.

So I will endeavor to portray in these few pages, and with the valued assistance of a few prized photographs, something of the biologic features characteristic of timber-line in the state of Colorado, and especially something about the peculiarly dwarfed and wrinkled and aged trees with which I have become more or less intimate.

The term timber-line is commonly applied to the upper limit of tree growth, whether that limit is an alpine or an arctic one. Beyond timber-line is the land of "little sticks," where there are no trees, but only miniature bushes, brilliant alpine flowers, mosses and lichens, and here and there enticing expanses of



TIMBER-LINE IS SELDOM A CLEARLY CUT AND STRAIGHT BOUNDARY LINE AT A UNIFORM ALTITUDE. Usually it is very irregular and jagged and it may swing up and down through an altitudinal amplitude of a thousand feet.

beautiful alpine pastures, the real *alps*. We must not understand that the upper border of the forest is in fact a clearly cut and straight boundary line at a uniform altitude or latitude as the case may be. Timber-line is commonly very irregular and jagged, and it may swing up and down through an altitudinal amplitude of a thousand feet or more, even upon a given mountain, or through several miles in the far north. Such fluctuations are related to numerous environmental obstacles some of which will be mentioned in the succeeding paragraphs.

THE TREES AT TIMBER-LINE

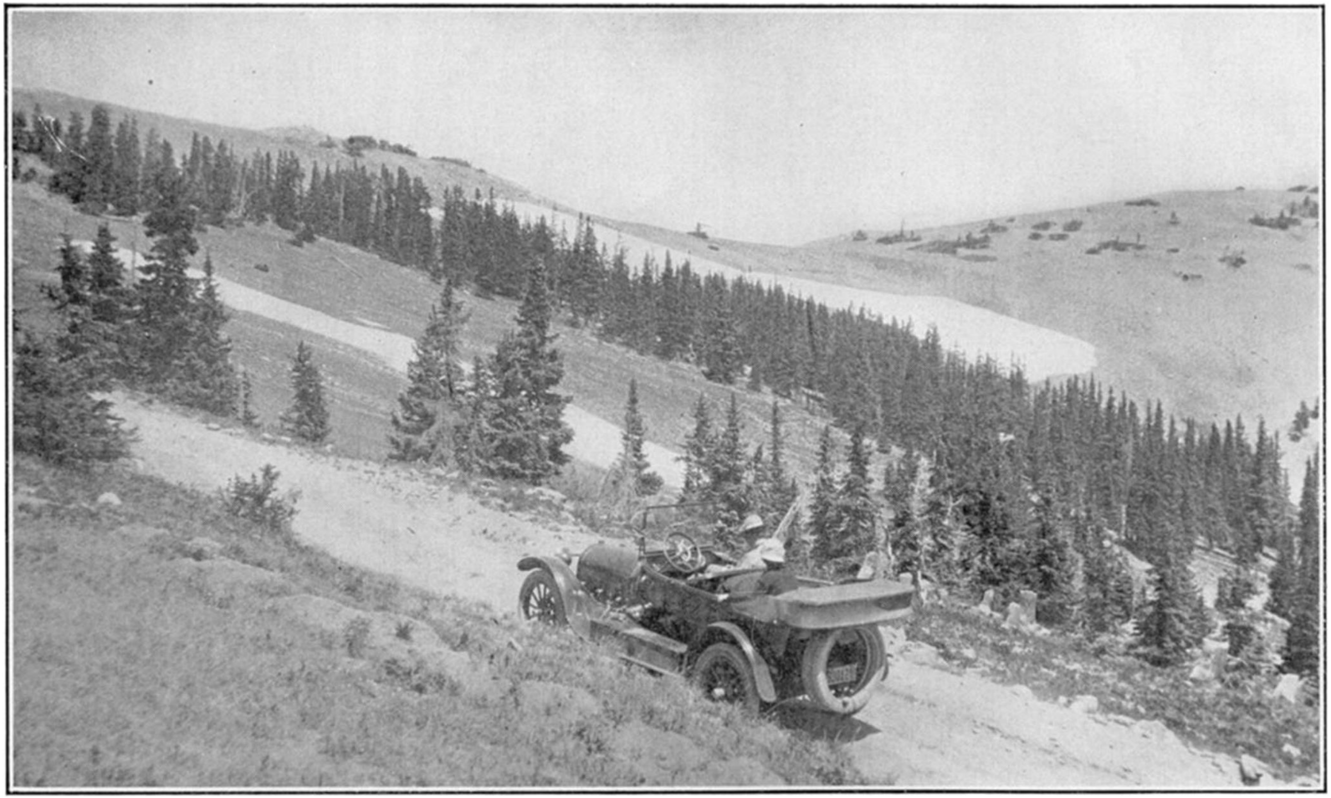
I have already stated that the most fantastic forms and perhaps, therefore, the most interesting phenomena of all in the most alluring medley of biological conditions at timber-line are seen in the dwarfed and wizened gnomes of the elfin-forest frontier. The commonest trees to reach the alpine forest limits in the Rocky Mountains of Colorado are limber pine (*Pinus flexilis*), and Engelmann spruce (*Picea Engelmanni*). Quaking aspen (*Populus tremuloides*), Alpine fir (*Abies lasiocarpa*) and fox-tail pine (*Pinus aristata*) also reach the front line trenches at timber-line, but are less frequently seen in such places.

The Engelmann spruce is seldom seen in the driest and most exposed sites. The species typically reaches its upper altitudinal limit in the form of scattered stands or isolated and more or less dwarfed individuals in the protection afforded by moist canyon heads. In such places one frequently finds a few poorly developed, erect, and excessively branched trees fringed at the base by an impenetrable thicket of scraggly and interwoven twigs produced by the multiplicity of lateral buds and branches. Such springy growths are excellent places upon which to enjoy a siesta, following a difficult climb.

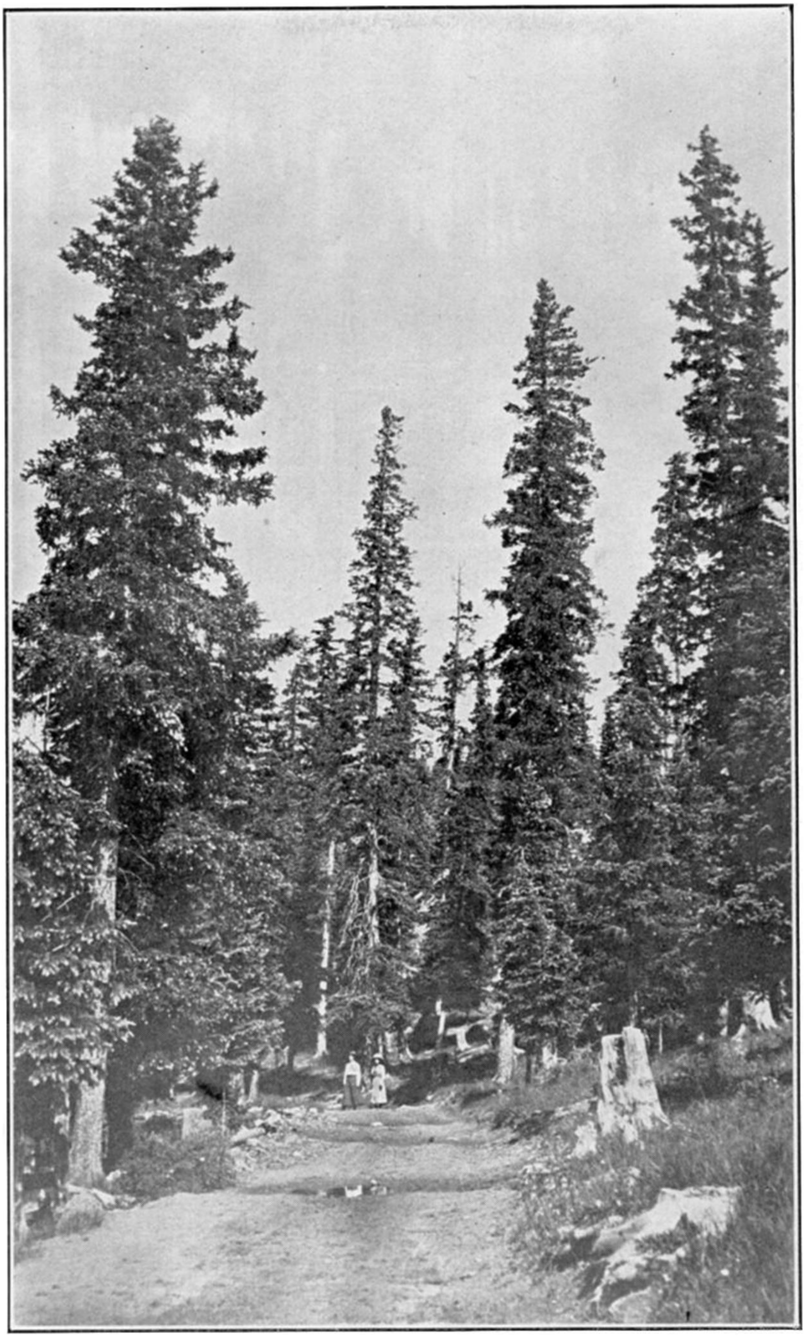
It is quite different, however, for the limber pine which often braves the elements upon the most exposed ridges where the outposts endure the buffeting of the dynamic surroundings for years. This tree is able to maintain a foothold upon dry open tracts in the very teeth of the furious gales that often swoop down upon them from the heights.

INDIVIDUALITY IN TREES

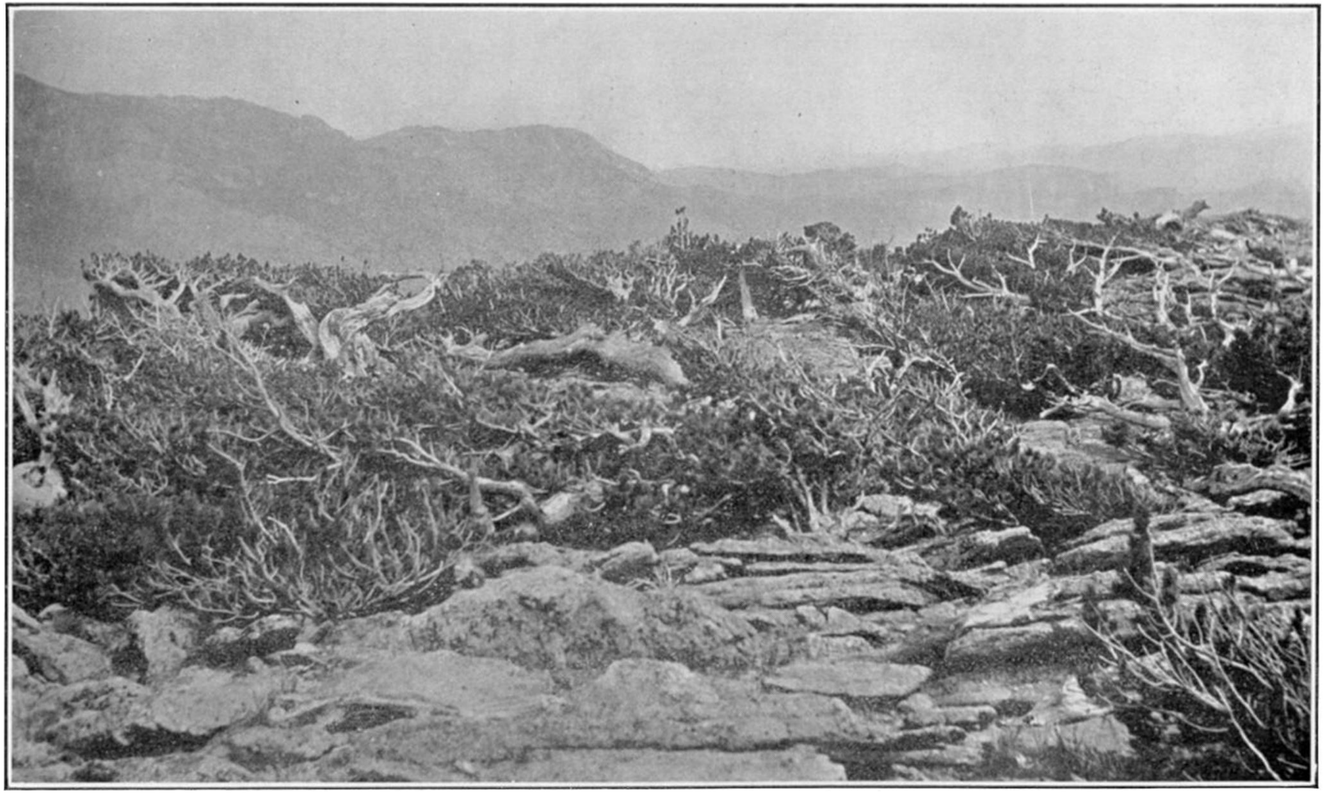
The individuality of the limber pines and the range in morphological reactions to the rigorous factors of their most extreme habitats are exceedingly varied and bizarre and are perhaps not to be equalled by any organism in any environment



Approaching timber-line with the Engelmann spruce. This tree is usually found in the moister habitats of the canyon heads at timer-line. It seldom occurs in the drier and more exposed sites with limber pine.



THE ENGELMANN SPRUCE IN ITS OPTIMUM SITE IS ONE OF THE FINEST OF AMERICAN CONIFEROUS EVERGREENS. It frequently reaches timber-line, but it is seldom found in the most severely exposed sites on that forest frontier.



MOST OF THE TREES WERE BENT TO THE LEEWARD AS THOUGH STANDING IN THE PATH OF SOME MIGHTY BEAST WHOSE TREAD HAD LITERALLY TRAMPED THE FOREST TO THE GROUND WHERE THE TREES WERE MORE OR LESS BURIED IN THE DÉBRIS OF THE AGES.

known to biologists. There are, in fact, scarcely two trees of this species to be found among the pioneers at timber-line that closely resemble each other in their bodily forms. Each tree appears to have worked out the solution of its own individual salvation under great stress and in its own individual manner. All this merely emphasizes the scarcely understood fact that plants do have considerable individuality even if they are not conscious beings.

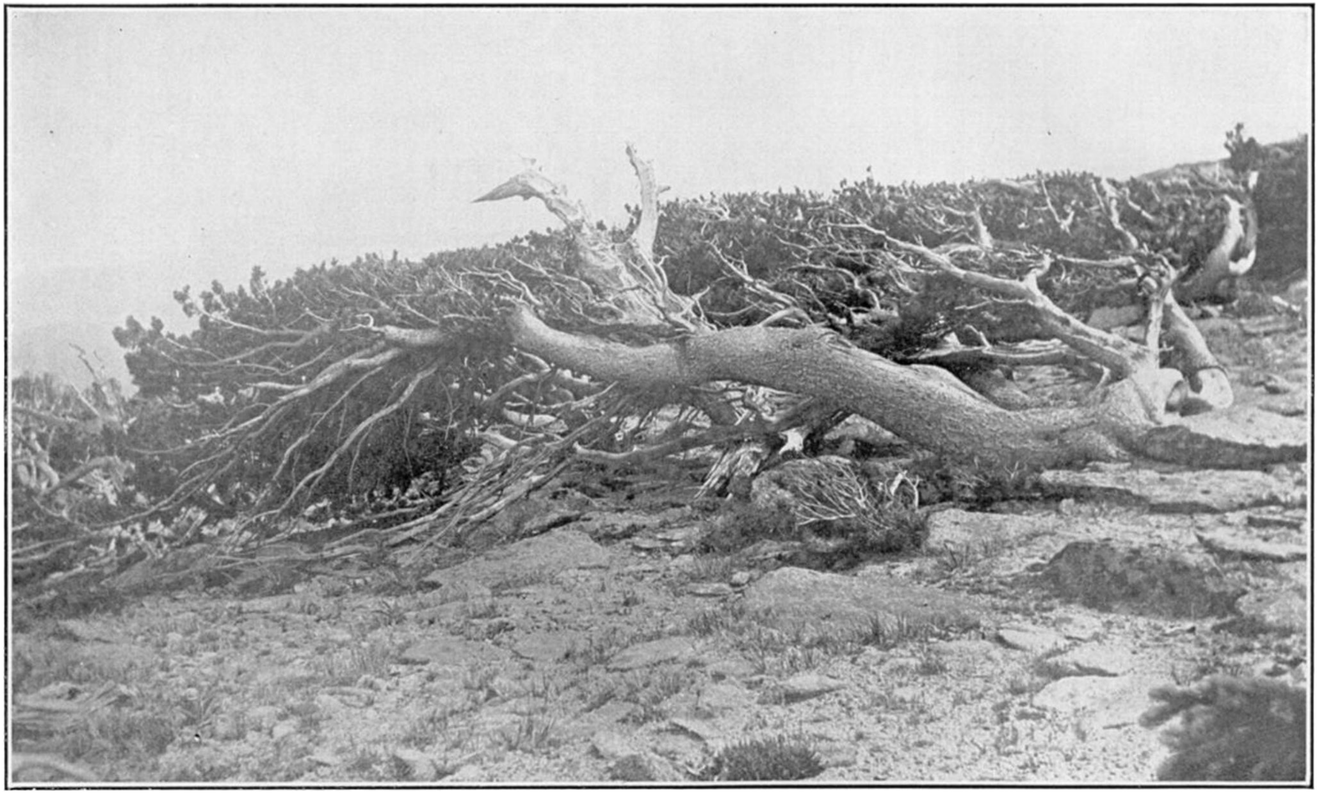
The limber pine belongs to the white pine group, a series of species whose remarkable qualities and beautiful forms are famous among coniferous evergreens. This species is, however, a rather small tree, rarely attaining a height of sixty feet and a trunk diameter of four feet at the base. It is usually a slowly growing, stout, bristly tree from twenty to thirty-five feet in height, with a sturdy, rapidly tapering trunk from one to two feet in diameter at the ground level as it grows in the more congenial habitats of altitudes below timber-line.

Almost every conceivable modification and deformity of the limber pines occur upon the wind-swept alpine slopes and exposed, xerophilous ridges at timber-line. In a jagged area of elfin-wood at an altitude of about 11,000 feet containing several hundred individual trees of this species I was able to study and to photograph scores of morphological variations and eccentricities, the most of them peculiar to the timber-line neighborhood.

Sometimes an odd, squatty form of the normal tree is seen where the blasting effects of the gales are not directly felt. Such trees may be a scant dozen feet tall, but have developed, through the long decades of their precarious life, a rapidly-tapering and gnarled trunk three feet in diameter at the surface of the sterile rock heap in which the cramped roots find anchorage. These fore-shortened trees are often of great age.

TREES OF GREAT AGE

One can not judge of the age of these timber-line trees by their size or bulk. If one could evaluate their grizzliness in terms of years he would thereby be enabled to make a closer estimate as to their ages, but that is quite impossible. The layers of growth (the so-called annual rings) in the wood of such trees are commonly so close together or so thin as to be indiscernible to the naked eye. The sheeted layers of wood are often so attenuated that a good hand lens or a dissecting microscope is required to count them with accuracy. I found that some pieces of the wood of the timber-line limber pines which I



THE TREES LIE WITH THEIR COARSE ROOTS FIRMLY ANCHORED IN THE SOLID ROCK OF THE MOUNTAIN SIDE, WHILE THEIR HEAVY TRUNKS STRETCH AWAY TO THE LEEWARD LIKE THE UNDULATING BODIES OF PONDEROUS, PREHISTORIC SAURIANS.

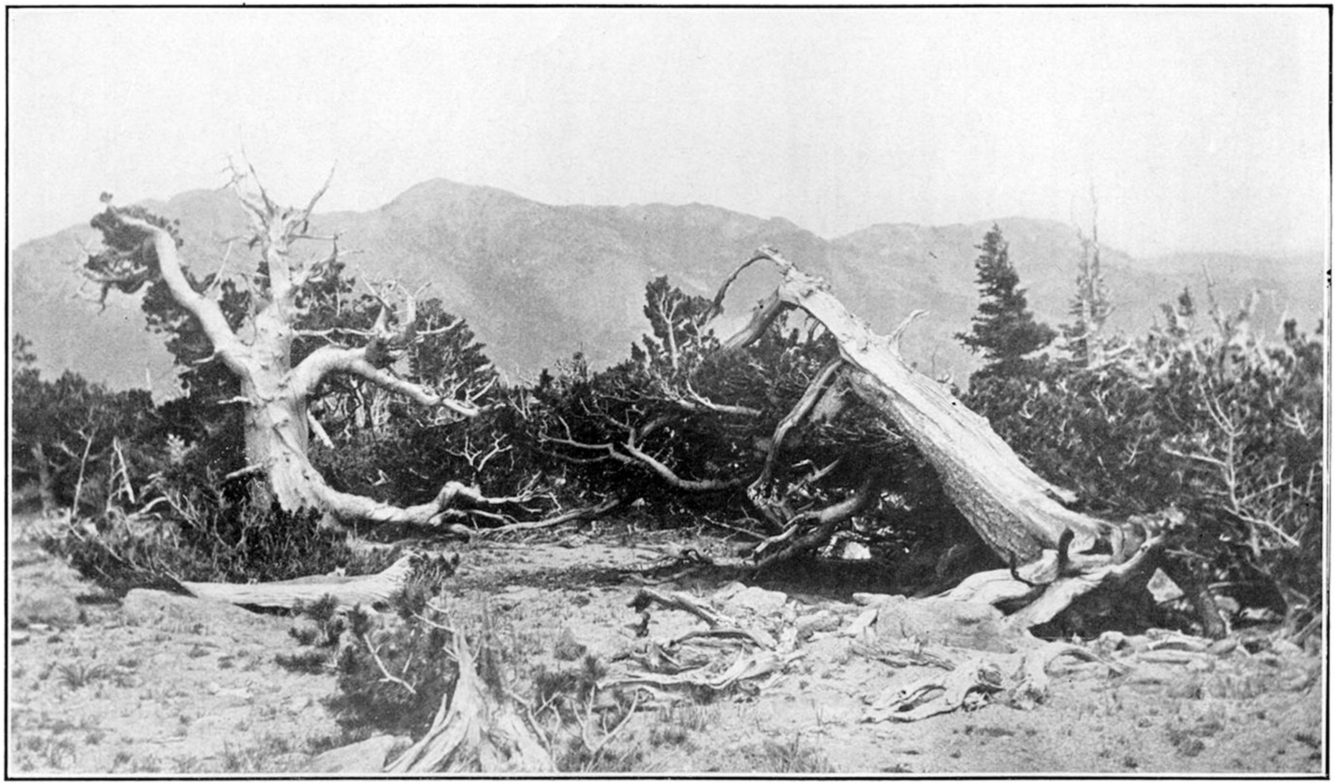
brought home from one of my trips were of astonishingly slow growth. Some such pieces were tangential strips of wood, less than one inch in thickness, and by actual count it was found that they contained between sixty and seventy annual layers.

Mr. Enos A. Mills, a well-known writer upon the numerous natural features of the Rocky Mountains, states that there may be great differences in the ages of timber-line trees standing close together and that the size of a tree is no criterion whatever as to its age. He writes of a tree fourteen feet in height and sixteen inches in diameter which was three hundred and thirty-seven years old. Another tree close by was seven feet tall, five inches in diameter, and it had endured the trying life on that frontier for four hundred and ninety-two years! Doubtless many timber-line trees have maintained their uncertain foothold and have pieced out their lingering existence by the production of a thin new layer of sapwood during each brief alpine summer since the time when Columbus piloted his frail caravels across the heaving bosom of the unknown Atlantic.

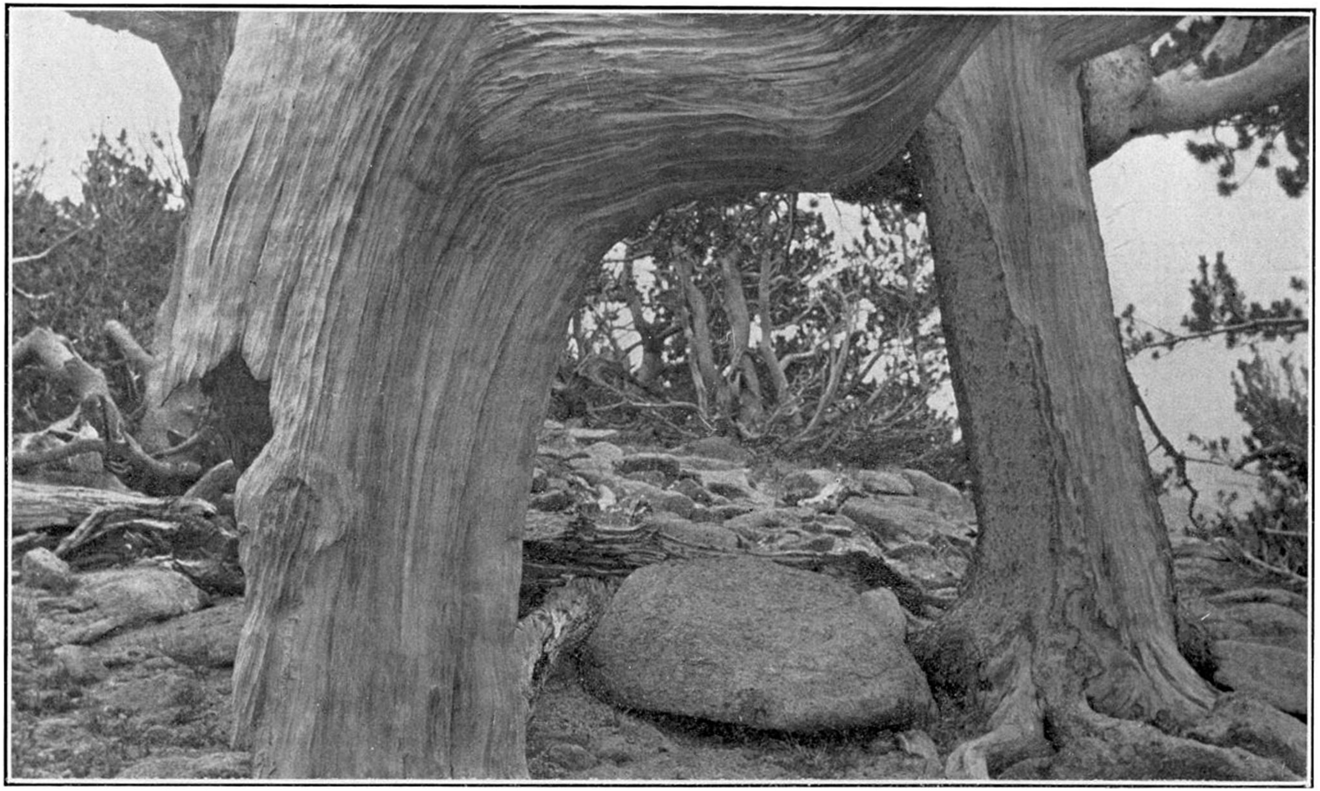
Wind-Crippled Trees

Besides the diminutive forms of the trees the most evident effects of the timber-line environment are undoubtedly seen in the wake of the winds which blow from a more or less constant quarter. Sweeping over some saddle or booming down the slopes the thundering blasts strike the sentinels of the forest and then sweep onward to the main body of trees farther down the slope. The immediate effect is to produce odd, lop-sided creatures more or less similar to those seen upon windy sea coasts. The crowns of the trees become distorted and bent to the leeward and often the whole tree is thrown out of the perpendicular, with a resultant deformity more striking than the sea-side cripples. The branches on the lee side stretch far out as if in flight before the oncoming blasts. The lateral twigs and the normally erect spray become pounded and woven into most astonishingly abnormal brushes and bristling tufts. The one-sidedness of such trees is frequently still further emphasized because of the failure of the branches to develop on the windward side or by the cutting away of any such branches by the incessant beating of the prevailing wind. I have examined some such trees in which there were absolutely no external indications of there ever having been any lateral branches on the windward side of the trunk.

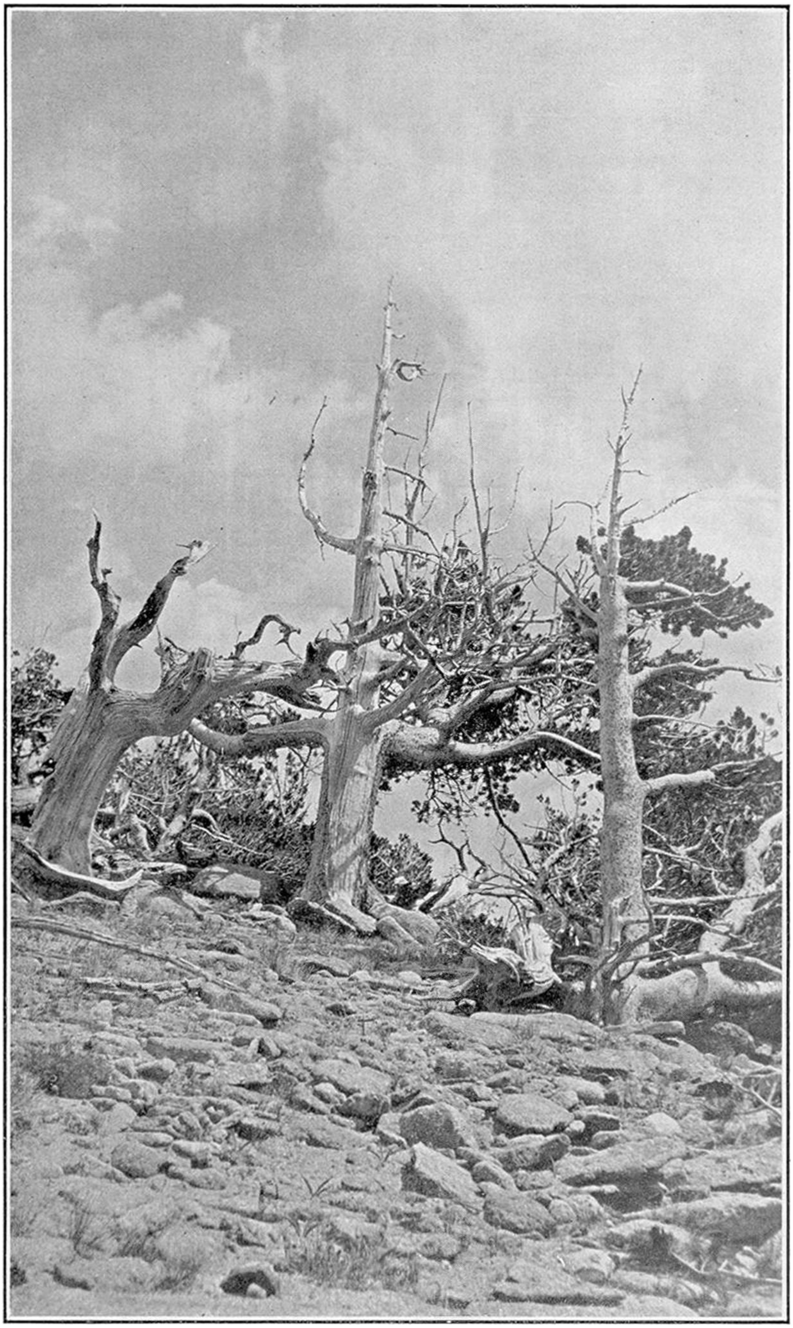
The extreme effect of the wind combined with heavy snowfall is seen in the development of prostrate trees lying upon



SUCH AGED AND SQUATTY TREES MAY BE A SCANT DOZEN FEET TALL, BUT THEY HAVE DEVELOPED, THROUGH THE LONG DECADES OF THEIR PRECARIOUS EXISTENCE, A RAPIDLY TAPERING AND GNARLED TRUNK THREE FEET IN DIAMETER AT THE BASE. They may be more than five hundred years old.



AFTER THE BARK HAS BEEN PULVERIZED AND WEATHERED AWAY THE TEETH OF THE WIND CONTINUE TO ETCH THEIR WAY INTO THE VERY WOOD ITSELF.



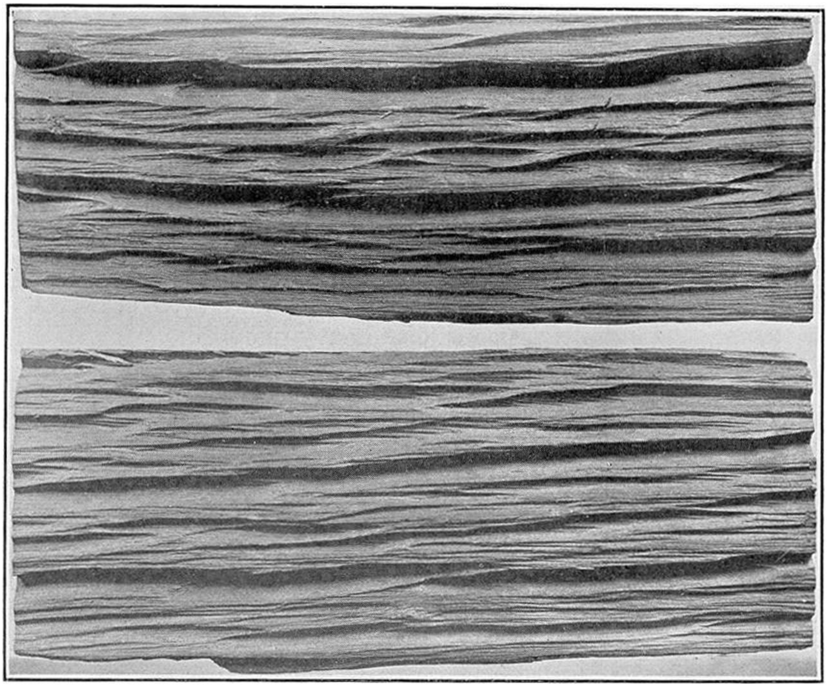
THE INCESSANT CHISELING OF THE WIND FINALLY ENDS THE LIFE OF THE DEFORMED STRUGGLER AND THEN ITS LIFELESS BODY STANDS OUTLINED AGAINST THE HORIZON LIKE THE EMACIATED FORM OF A CRIPPLED GIRAFFE GROWN GAUNT FROM LACK OF FORAGE AND DRINK.

the stony surface of the wind-blown mountain floor. These trees lie with their coarse roots anchored firmly in the solid rock of the mountain side, while the heavy trunks stretch away to the leeward like the undulatory bodies of ponderous prehistoric saurians. One such tree eighteen inches in diameter and twenty-five feet long had had all of the branches on the upper surface planed away by the abrasive sand and sleet carried by the wind, while the living twigs were segregated in the usual tangles toward the end of the prone form. The flattened forest at that point as portrayed by the above trees illustrates the unmistakable influence of the heavy snowfall at high altitudes. None of the trees in that prostrate group raised a twig higher than five feet above the ground. The most of them were flattened out and bent to the leeward as though standing in the path of some mighty beast moving with the breeze and whose tread had literally tramped the forest to the ground, where the trees were more or less buried in the débris of the ages. In less exposed situations the trees assume a more nearly erect posture, but even there the knotted, twisted and burly forms are sometimes riven by lightning and disheveled by the blasts of Boreas and his heavy mantle of snow until they totter like a drunken man and almost fall to the earth.

The dwarfed, gnarled, twisted and sprawling trees at timber-line have been known to botanists by the term *Krummholz,* which is German for *gnarled wood.* The term was originally applied to the high altitude form of the mountain pine (*Pinus montana*) of the Alps. In late years it has been used widely as a general term for the scrubby and bizarre growth of woody plants at or in the vicinity of timber-line on mountains in any part of the world. It is surely a very expressive and useful term.

As one strolls among the various forms at timber-line he occasionally finds a curious entanglement of scraggly, woody growth lying in the shelter of a low boulder or snuggling beneath the projecting angle of a cliff. In such places the branches and leafy tufts are trimmed smoothly away on a level with the surface of the protecting obstacle. The twigs of such trees often become so densely interwoven and so tough that one may walk over the prostrate, hedge-like form without breaking far into the brush beneath the surface.

The degree of exposure to the wind and the influence of heavy snow appear to be most effective in modifying the forms of the trees at timber-line. The effects of snow are also seen far below the upper limit of tree growth, particularly in



SO DEFTLY ARE THESE WIND-CARVINGS EXECUTED BY THE FINGERS OF THE WIND THAT THEY DEFY THE BEST EFFORTS OF A SKILLED WOOD CARVER WHO WOULD ATTEMPT TO IMITATE THEM. The above pieces show the effect of wind erosion in comparatively straight grained wood.

thickets of quaking aspen trees. There one occasionally notices that the trees are bent and twisted and crooked into multifarious contortions at a certain height. I once saw such a striking condition in a grove of young aspens about twenty feet tall. The distorted portions of the trunks were completely confined to a zone between five and seven feet above the ground. And every tree of the several hundred in the grove was affected. Very evidently the cause of such a peculiar-looking condition was to be found in snow relations, coupled with the growth habits of the trees.

WIND, THE WOOD CARVER AT TIMBER-LINE

An additional point of great interest in connection with my studies of the *Krummholz* at timber-line in Tahosa are the fantastic wind-carvings produced in the wood of the decorticated tree trunks. The winds at timber-line often blow with a high velocity and then they carry with them quantities of sharply angular rock fragments weathered away from the very backbone of the mountains. During the long winter months this load of abrasive material is augmented by the presence of quantities of snow and ice spicules. The fine mineral particles have been so recently removed from the parent rocks that they are exceedingly sharp-angled and pointed. This feature increases their abrasive influence as they are carried along by the wind. A winter gale thus laden, sweeping over the heights, may in truth be said to possess teeth, the "teeth of the storm."

I have already pointed out the fact that the windward sides of the tree trunks at timber-line are sometimes devoid of branches. Frequently the bark also has been cut away from that side. The tree may be nearly girdled by the powerful grinding effect of the sand and sleet carried in the high wind. Often only a slender longitudinal belt of living bark is left on the lee side of the tree to carry the necessary life-giving substances from the meagerly developed expanse of foliage to the hard-working root system pinched and cramped in the crevices of the rocky substratum. The breakage of this connection is doubtless an important factor in the final death of the trees which grow in the most exposed sites. The incessant hammering and chiseling of the wind ultimately ends the lingering life of the deformed struggler and then its lifeless body stands there outlined against the horizon like the emaciated form of a crippled giraffe grown gaunt from lack of forage and drink.

After the bark has been pulverized and weathered away the teeth of the wind continue to etch their way into the wood itself. The thin, young and less resistant sapwood is soon removed and then the harder, resinous heartwood is attacked, upon the surface of which are cut the intricate traceries of the fingers of the wind. So deftly are these carvings executed that they defy the best efforts of the most skillful wood carver who would attempt to reproduce them. Their imitation is impossible because the fingers of the wind have felt out the variations in hardness and structure of the wood with a delicacy of perception far beyond that possessed by a mere human being. The result is the production of wood carvings of remarkable beauty and variety. The unevenly resistant wood and the intricate variations in the grain of the slowly and irregularly growing wood are strikingly mirrored in the variation of detail in the individual trees. The most beautiful effects of all such wind influences are seen in those tree trunks and branches in which the grain is more or less distorted. Thus the spiral growth, wavy grain effects, and the extreme disturbances of normal wood structure in knots and burls, coupled with variations in wood density, are emphasized in a very remarkable and often beautiful degree upon the dead surfaces of the storm-tossed trees at timber-line. The erosion of the woody bodies continues after death and serves still further to multiply the fantastic and weird effects of the environment in which the *Krummholz* is developed. Even the fragments of the dismembered bodies of the ancient gnomes are blown about and sculptured until they lose nearly all semblance to any plant structure. Waugh's uniquely illustrated and more or less spooky fairy tale, "The Clan of Munes," might find a natural sequel among these grotesque forms at timber-line.

TIMBER-LINE CONTRASTS

It is only with great difficulty and careful study that the occasional visitor is able to acquire an adequate appreciation of the peculiarly rigorous environmental conditions at timber-line. This is particularly true for him whose visits to timber-line are made only during the relative peace and quiet of a warm summer day when the alpine meadows and fell-fields are ablaze with the blooms of gorgeous wild flowers and when all living nature on the heights is humming with the busy opportunity for life and propagation afforded by the short hours of a brief growing season. The first blush of vernal bloom has scarcely faded upon the alpine heights ere the seeded capsules of arctic willow and primrose and the hoary plumes of Dryas give warning of the early approach of old Boreas with his host of forces to try the last fiber of every living thing at timber-line throughout the long, cold winter. No more striking contrast can be found in nature than that seen in the silent places where brilliant wild flowers bloom in lavish profusion within the shadow of frowning cliff and the storm-marked and ghostly *Krummholz,* where the youthful brook gurgles along its silvery path hard by where the trustful Ptarmigan silently guards her young, and where the warm sunshine and cloud-bedecked, summer sky covers all. John Muir's words are expressive in this connection: "Nature's sources never fail. Like a generous host, she offers her brimming cups in endless variety, served in a grand hall, the sky its ceiling, the mountains its walls, decorated with glorious paintings and enlivened with bands of music ever playing."

Besides the limber pine and the Engelmann spruce which enter most prominently into this sketch there are several other species of coniferous trees which reach timber-line in other portions of the continent. White spruce (*Picea canadensis*) and balsam fir (*Abies balsamea*) in the New England mountains; alpine fir (*Abies lasiocarpa*), white-bark pine (*Pinus albicaulis*), and fox-tail pine (*Pinus aristata*) in the Rocky Mountains; and the mountain hemlock (*Tsuga mertensiana*) from Oregon to Alaska are other trees which share in the development of timber-line phenomena.

The altitude of the alpine timber-line varies more or less inversely with latitude, *i.e.*, the upper limit of tree growth on mountains is encountered at a lower altitude as one travels northward, as latitude increases the altitude of timber-line decreases. In the far north timber-line comes down to the shores of the icy sea shortly beyond the Arctic circle. The altitude of timber-line in the Canadian Rockies varies from 5,000 to 6,000 feet. On Mt. Rainier it is about 7,000 feet, while in central Colorado it is reached between 10,000 and 12,000 feet. The highest timber-line in the world is said to occur in Mexico, as on Mt. Orizaba, at an altitude of 14,000 feet, which is reached by *Pinus strobiformis*, one of the southwestern white pines.

THE CAUSES OF TIMBER-LINE REACTIONS

The limitation of tree growth at certain altitudes in the mountains has never been adequately explained. Unquestionably the cause or causes are to be found somewhere in the maze of interacting or overlapping factors brought to bear upon the life at timber-line. The ecological relations there are apparently very complex and until much more quantitative research has been completed within those dynamic habitats biologists will be unable to point out the cause of timber-line with surety. The effects of wind are unmistakably chiseled into the prominent reactions of the trees, some of which have been poorly and inadequately described in the preceding paragraphs. The effect of heavy and long-persisting beds of snow are probably of importance in restricting the growth of forests at high altitudes. Certain investigators have felt that snow is the chief factor which inhibits the development of a forest of normal trees at certain altitudes and is responsible for the development of alpine grasslands instead of forest. Others believe that the desiccating influence of the winds, coupled with a deficiency of available water supply at the roots and a low temperature, largely explain the stunted nature of the woody growth at timber-line. Atmospheric rarity, intense insolation, rapid radiation, low relative humidity, and short growing seasons have also been proposed as playing important rôles in the production of alpine dwarfs and possibly in actually causing timber-line.

Experiments appear to have demonstrated that the dwarfing is actually due to the alpine conditions. Portions of alpine plants moved to the lowlands promptly awakened from their dwarfed state and developed the characteristic lowland forms with tall stems, while portions of lowland plants established in alpine sites promptly became dwarfs.

Snow-cripples, drought-cripples and dwarfs as well as wind-cripples and dwarfs probably occur within timber-line areas. Numerous similarities existing between alpine and polar growth forms and the vegetation of desert lands have led to the belief that the whole relation is one of aridity. Arctic-alpine habitats have been included among the desert series in ecological classifications of habitats.

The prevailingly low temperature summation is doubtless of great importance in limiting the activities of the plants at timber-line and consequently in modifying the growth forms most efficient or possible there. In this connection I once recorded some observations upon the matted forms of the alpine pink (*Silene acaulis*) growing in a gravelly slope on Mt. Garfield in the vicinity of Pikes Peak. The flat, bristly, mat-like plant, beautifully radiate in form, was about eighteen inches in diameter and was growing where it was partially shaded by a large boulder. The shaded portion of the mat was evidently not in as good condition as the portion which received the direct rays of the sun, in fact it possessed many of the well-known weakly characteristics of shade plants in general. But the influence of the sun (heat or light) was very evident the day I made the observations because of the production of flowers on the plant. The arctic pink at blooming time is often literally covered with scores of the beautiful pink flowers about five-sixteenths of an inch wide. The lighted portion of the mat in this case, the portion receiving the direct rays of the sun at noon-day, was about one half of the whole plant and was blooming profusely, while the portion in the cool shade of the rock showed very few open flowers or flower buds.

A primary task of all green plants in timber-line situations is certainly to utilize the heat and light of the sun in the manufacture of the food supply necessary for leaf and root formation and for reproduction if they are to remain in such places. Essential nutritive materials must be secured *via* the root-system from the cold soil solution at the same time. Any condition of air or soil which tends to block these fundamental processes for long periods of each year strikes at the very life of the plants in question, and consequently would exert a significant influence upon the initial establishment and the subsequent success of the plants on the heights.

These are but a few of the impressions and problems which are suggested on every side to the inquisitive wanderer among the plant pigmies at timber-line in the land of Tahosa.